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Three horticulturally significant exotic species as new generic and specific additions to the myrtle family of Kerala

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Abstract

Recent collection of three exotic species of family Myrtaceae *viz*. *Xanthostemon chrysanthus* (F.Muell.) Benth., *Plinia cauliflora* (Mart.) Kausel and *Acca cellowiana* (O.Berg) Burret from the home gardens of Kerala, signifies three new generic and specific additions to the myrtaceous flora of Kerala State.

Keywords: Myrtaceae, New addition, Exotic, Kerala.

Introduction

The State of Kerala, situated in the south-western corner of Indian peninsula, harbors a rich diversity of indigenous as well as exotic plant species, which is especially reflected in the Myrtaceous group. In Kerala, the family Myrtaceae is represented by more than 69 species under 9 genera viz. *Callistemon, Eucalyptus, Eugenia, Melaleuca*, *Meteoromyrtus, Pimenta, Psidium, Rhodomyrtus and Syzygium*. Of these, *Meteoromyrtus* is a monotypic genus and has recently been synonymized under the genus *Eugenia* L. as *E. wynadensis,* based on advanced molecular and taxonomic studies (Byng *et al*., 2015; Wilson and Holsewood 2016). Out of the 69 species reported from Kerala, 17 are exotics (Sasidharan, 2004; Nayar *et al.,* 2006, 2014; Shareef *et al*., 2018; Vadhyar *et al.,* 2019; Shareef, 2020; Shareef and Santhosh kumar, 2020).

While surveying the Myrtle family of Kerala, the present authors collected three horticulturally important exotic species, grown in different home gardens of the state. On critical study covering authentic literature, the three species were identified as *Xanthostemon chrysanthus* (F.Muell.) Benth., *Plinia cauliflora* (Mart.) Kausel and *Acca cellowiana* (O.Berg) Burret respectively. Further, it also revealed that the species have so far not been included in any of the floristic documentations of Kerala. The present collections therefore form three generic *viz*. *Xanthostemon* F. Muell., *Plinia* L. and *Acca* O. Berg and three specific additions to the Myrtaceous flora of Kerala. A short description with scientific names, common names, nativity, uses and field numbers of the specimens gathered are presented. The herbarium specimens deposited in TBGT.

Xanthostemon chrysanthes (F. Muell.) Benth.
'Golden penda'

Large shrub to medium trees, to 10–15 m high. Leaves elliptic or oblanceolate, thin coriaceous, 7–22 × 2–9.5 cm, arranged in whorls along the stem, tapering at base, acuminate or acute at apex. Petiole short. Racemes terminal or axillary, to 15 cm in diam. Flowers small, 1–2 cm across, golden yellow; calyx tube broadly campanulate, 3-5 mm diam.; lobes ovoid-deltoid. Petals orbicular.

Fruits round, 1–1.5 cm across, green or brown woody capsules. (Figure 1.A)

Fl. & Fr.: Almost throughout the year.

An endemic tree in northeastern Queensland, Australia. Now, it is cultivated as an ornamental tree in different countries. *SMS 79277*

Plinia cauliflora (Mart.) Kausel
'Jabuticaba'

Slow growing, multi-branched shrub or small trees, to 10m high. Bark reddish- brown flaking. Leaves lanceolate or elliptic, chartaceous, 2.5–6 × 1.25–2 cm., rounded at base, acute or acuminate at apex. Petiole 2 mm long, hairy. Young leaves salmon coloured. Flowers small, white, cauliflorous, solitary or clustered. Sepals lanceolate. Petals elliptic, white. Fruit thick skinned berry, to 2–3 cm diam., dark purple when ripe. (Figure 1.B)

Fl. & Fr.: March – May

Native to Minas Gerais and Sao Paulo states in southeastern Brazil. Cultivated in home gardens as edible fruit tree. *SMS &TS 79283*

Acca cellowiana (O.Berg) Burret
'Feijoa'

Slow growing shrub, 3- 6 m high. Leaves elliptic, 2.8–6.25 × 1.6–2.8 cm, silvery pubescent beneath, obtuse at apex, cuneate at base. Flowers solitary or clustered, terminal or axillary, 2.5 cm across; calyx tube funnel shaped; petals fleshy, ovate-elliptic, white tomentose without, purplish within; stamens scarlet. Fruits oblong, ovoid or slightly pear-shaped, 4–6 × 2.8–5 cm, blue green or pale green. (Figure 1.C)

Fl. & Fr.: May–July.

Native to the highlands of southern Brazil, eastern Paraguay, Uruguay, northern Argentina, and Colombia. Cultivated as garden plant and edible fruit tree. *SMS 79295*

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Legends of figures

Figure 1. A. *Xanthostemon chrysanthes* (F. Muell.) Benth.

B. *Plinia cauliflora* (Mart.) Kausel

C. *Acca cellowiana* (O.Berg) Burret

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A. *Xanthostemon chrysanthes* (F. Muell.) Benth. B. *Plinia cauliflora* (Mart.) Kausel C. *Acca cellowiana* (O.Berg) Burret

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Ecological niche modeling for conservation planning of *Vanda wightii* Rchb.f. a notified endangered orchid of Western Ghats, India

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Abstract

Ecological niche modeling is a machine learning technique recognized as tool to identify suitable habitat for conservation action. The present study describes habitat modeling of *Vanda wightii*, a notified endangered orchid species of Western Ghats, India for conservation implication. A total of 19 bioclimatic variables subjected to principal component analysis extracted into 3 components based on temperature and precipitation. Representative variables from each component in all possible combinations resulted consistent output showing suitable climatic conditions for the species extending from Thiruvananthpuram District of Kerala to Dakshina Kannada district of Karnataka. Habitat suitability was confined to the regions receiving an average 3518mm annual mean precipitation, 11.4°C temperature annual range and 323cm precipitation in the warmest quarter. The highly suitable habitats fall mostly in inhabited land in Dakshina Kannada, Kasargod, Kannur, Malappurarm and Palakkad Districts. Protected forests in Kerala outside distribution range also hold sufficient habitats for restoration of *V. wightii*. Conservation introduction in one such locality at JNTBGRI campus showed 63% establishment and luxuriant growth of seedlings. Thus the study revealed ecological niche modeling as an effective tool to identify suitable habitats for conservation of *V. wightii*.

Key words: Conservation, endangered species, maxent modeling, Orchids

Introduction

The stability of an ecosystem depends on its biodiversity components and thus developing effective strategies for their conservation needs considerable attention. Information on the present population and extent of distribution of a threatened species is also important for conservation planning (Štípková *et al.* 2020). *Vanda wightii* Rchb.f. is one among the five Vanda species of Western Ghats endemic to Southern Western Ghats, India and SriLanka demanding conservation action. It is originally described by Raichenbach.f (1864) based on Robert Wight‟s collection from Vaulyar and Palghatcherry (1849) and Thwaite‟s collection from Sri Lanka (Satheeshkumar *et al.,* 2006). It is supposed to be extinct as it has not been re-sighted in the wild ever since Wight‟s collection (Limansela *et al.,* 2002). Later during 2000-02 periods, the species is re-collected from Belthangady and Subramanya in Dakshina Kannada district of Karnataka; Nidiyanga in Kannur and Melattur near Palakkad district of Kerala (Satheeshkumar *et al.,* 2006).

The species is described as distributed in narrow pockets with restricted numbers and later under section 38 of the Biological Diversity Act 2002, the Central Government notified that *V. wightii* is on the verge of extinction and prohibited/regulated collection (MOEF, 2009). The ministry also called for studies on all aspects of the notified species for holistic understanding and propagation of the species for the purpose of *in situ* and *ex situ* conservation and rehabilitation.

Mapping the identified geographical locations and predicting potential distribution of a species based on the presence records is known to be helpful in identifying critical regions that may need conservation action (Warren and Seifert, 2011). In this context, ecological niche modeling using maxent software (Phillips *et al*., 2006) is recognized as an efficient tool to understand the distribution extent of a plant/animal species and widely used to develop suitable models (Peterson *et al*., 2011, Elith *et al*., 2011). These models establish relationships between occurrences of species and biophysical and environmental conditions in the study area thus predicting suitable habitat for survival and existence of a species. This technique was successfully applied to find potential distribution and identify environmental niches for several plant species including orchids as *Vanda bicolor* (Deb *et al.,* 2017), *Paphiopedilum javanicum* (Romadlon *et al.,* 2021) and *Habenaria suaveolens* (Jalal and Singh, 2017). Based on the current understanding and the requirement of devising conservation action, the present study is framed to understand the habitat suitability of *V. wightii* in Western Ghats region of Kerala and Karnataka States in India.

Materials and Methods

Study site and field survey: As per the cited literature, Palakkad, Coimbatore, Nidiyanga, Melattur, Belthangady, Subramanya, Mangalapuram, Idukki Wildlife sanctuary, Kasargod and Goa are the reported localities of *V. wightii* in India (Sathishkumar *et al.,* 2006; Decruse, 2014; Jalal and Jayanthi, 2016). It is an epiphytic orchid (Figure 1) reported to have distribution at 60-80m altitudes inhabiting on hosts as *Terminalia paniculata, Mangifera indica*, *Strychnos nux-vomica* and *Tectona grandis* in tropical dry deciduous forests. Therefore, inhabited land mainly wayside trees, forest fragments and sanctuaries in Kasargod, Kannur, Malappuram, Palakkad and Idukki district mainly focusing on natural hosts were surveyed and geographical coordinates of occurrence points recorded using Garmin GPSmap 60.

Distribution modeling: The 19 bioclimatic variables of WorldClim version 2 for 1970-2000 at 1Km spatial resolution (Fick and Hijmans 2017) biologically more meaningful to define eco-physiological tolerances of a species (Graham and Hijmans 2006; Murienne *et al*., 2009), downloaded from http://www.worldclim.org/ bioclim.htm were used as the environmental variables for modeling studies. As habitat modeling was done for Western Ghats, the world data was clipped with respect to the Peninsular India in QGIS. The climatic variables are derived from temperature and precipitation data and thus multi co- linearity always exists among different variables which may interfere with interpretation of variable contributions. Therefore, principal component analysis (PCA) is often recommended (Junior and Nobrega, 2018) to control the negative effects of co-linearity and as a more objective solution for the problem of variable selection. The data points of all the 19 variables corresponding to the geo-reference points of *V. wightii* occurrence in 1KM spatial resolution were extracted using point sampling tool in QGIS and PCA analysis undertaken in SPSS 16 software to sort out the variables having significant contribution to the model. Accordingly, 3 major components were extracted (Table 1) explaining 99.5% of variance. The first 2 components contained 3 variables and after fixing one, other two variables showed variance inflation factor (VIF) above 10 (Table 1) and thus only one was used for modeling. Thus the variables Bio_7, Bio_12 and Bio_18 were included at a time in the final modeling procedure. Other possible combinations were also tested to confirm consistency.

Maxent software version 3.40 (Philips *et al*., 2006) was used to build a habitat suitability model. In this modeling, 75% of the encounter data was used for the training set and the rest for the test set. The modeling used auto features with 500 iterations and other default values. For validating model robustness, 12 replicated model runs was executed with a threshold rule of 10 percentile training presence and employed bootstrapping method for dividing the samples into replicate folds. The output of the Maxent software predicts habitat suitability in the range 0 (not suitable) to 1 (appropriate) (Phillips and Dudik, 2008). For selection of most important environmental variable, Jack knife test was performed. The output was imported to QGIS and a distribution map was created and prediction area calculated.

Restoration through Conservation Introduction at JNTBGRI campus: JNTBGRI campus appeared as one of the suitable habitat for *V. wightii,* out of its distribution range, as per the habitat model. Therefore, a restoration attempt was made through conservation introduction at JNTBGRI. Seedlings from five different populations of V. *wightii* were raised through seed culture and reared in the nursery for 1-2 years. Then the seedlings were tied onto pieces of bark of *T. paniculata* and grown for 2 months under controlled conditions (Figure 5a.) and then tied onto trunks of natural hosts (*T. paniculata, T. grandis*) in a forest segment of JNTBGRI campus. Both the hosts harbor the Vandaceous orchids *Acampe praemorsa* and *Vanda testacea* as natural recruits. The planting was made during monsoon period and the plants were allowed to grow by themselves without any special care. The data on survival and establishment was recorded every year up to 5 years.

Results and Discussion

Conservation assessment requires sufficient field surveys and gathering of primary data on the distribution of species and their population status. This is an exhaustive process which has not been taken seriously in India and therefore the availability of primary data is scanty. Conservation planning and action monitoring of a species initially require prioritization through threat assessment (Master, 1991; Moran and Kanemoto, 2017). *V. wightii* is an epiphytic orchid endemic to Indian Peninsula and SriLanka hidden unknown for over 100 years until 1998 when discovered a few populations from Kerala (Sathishkumar *et al.*, 2006). Based on the information on herbarium data, Government of India notified the species as endangered preventing further loss, but invited studies on all aspects of the notified species for conservation. The species is unique in its exquisite flowers but remain unexploited in recombination breeding as not accessible to breeders. However, as part of a sponsored project supported by DBT, Government of India, detailed study has been undertaken to prepare a habitat suitability model for conservation of the species.

Field Survey and modeling studies: Extensive field surveys revealed the distribution of *V. withtii* at altitudes from 27 to 1005m m.s.l mostly on deciduous trees as *Terminalia paniculata*, *Tectona grandis* and *Strychnos nux-vomica* exposed to sunlight. A total of 185 occurrence points from sanctuary, forest fragments, wayside trees and reserve forests were recorded in Kerala and Karnataka. Higher number of records was localized in two locations, one in Kasargod forest fragment and another in Idukki Wildlife sanctuary and thus only about 54 records were at 1KM resolution (Table 2) and used for modeling. The 19 variables subjected to principal component analysis extracted into 3 components explaining 99.5% variance (Table 1) and the final model based on three representative variables revealed temperature annual range as the environmental variables with highest gain and precipitation in the driest quarter exhibited significant drop when it is omitted (Figure 2). Therefore, the latter two variables are influencing mostly the distribution of *V. wightii*. The model based on other combinations with Bio_5, Bio_9, Bio_13 and Bio_16 also resemble with the representative variables except minor deviation in percentage contribution and permutation importance. The distribution map generated (Fig 3) indicate that 82.5% of the occurrence points fall in highly suitable (0.8-1) region and 34% in the moderately suitable (0.6-0.8) region (Figure 4). The whole peninsular India was modeled where only 2.1% area (42256Km^2; Figure 4) mostly in the inhabited land in Kasargod, Kannur, Palakkad, Malappuram and Idukki districts of Kerala emerged as suitable habitats for *V. wightii*. The Suitable habitats extend from Dakshina Kannada district of Karnataka to Thiruvannthapuram District of Kerala. However, so far there is no occurrence record towards south beyond Idukki. The occurrence record in Goa as per earlier report (Jalal and Jayanthi, 2016) appeared in the least suitable region. In spite of highest number of occurrence points in Kasargod forest fragments; this region was modeled in the moderately suitable region (0.6-0.8 class). Therefore, a shift of suitable habitat towards south is possible in future as the modeling result with environmental data of 1960-90 (Decruse, 2014) did not show regions in Thiruvananthapuram and Kollam as the suitable region. Also, it was experienced during our field survey in Kasargod that the *V. wightii* plants are facing severe stress during summer season due to altered precipitation pattern.

The maxent output (Table 3) revealed that variables in the 3 principal components contribute significantly to the distribution model. *V. wightii* inhabits the regions receiving 11.44±0.67°C temperature annual range, 3518±1190mm annual precipitation and 323.1±30.2mm precipitation in the warmest quarter (Table 4). Incidentally, *V. wightii* can grow at temperatures as low as 16.1°C in the coldest period and as high as 34°C in the warmest period. Maximum temperatures during the warmest period also should be in the range 26.7-33.7°C and Minimum temperature of the coldest period in the range 16.1-21.2°C. In the Western Ghats region of Kerala, between North

West and North East precipitation, there exist about 6 month gap. For the survival and optimized growth of such orchids, the long monsoon gap is not conducive. Therefore, the precipitation during summer is also very crucial for *V. wightii* and thus precipitation during the warmest period (Bio_18) emerged as one of the variable contributing significantly to the model.

Niche modelling is accepted as an economical and effective tool to prepare guide maps for intended plant survey and delineation of conservation areas for selected species (Adhikari *et al*., 2012). Such procedures definitely improve the availability of primary data on the distribution of species and their population attributes for better threat assessment and more accurate categorization of endangered species (Adhikari *et al*., 2018). Georeferenced occurrence points and environmental data pertaining to the distribution area are the two prerequisite for habitat modeling. Environmental variable as 19 bioclimatic variables and digital elevation are observed as biologically meaningful to define ecophysiological tolerances of a species (Grham and Hijimans 2006; Murienne *et al.,* 2009) and generally utilized for modeling studies. However, the bioclimatic variables are derived from temperature and precipitation data and thus often expresses multi co-linearity and thus often difficult to select the decisive environmental variables and their contributions. Principal component analysis and regression analysis executed on them reduced the number of factors into three still explaining 99.5% variance. Environmental variables showing VIF less than 10 are also included as the existing co-linearity is considered less significant below that value (Naimi *et al*., 2014). In this study, we could extract 2 components with 3 variables and one with single variable. Thus, after excluding variables with VIF greater than 10, 3 variables were retained to determine habitat suitability of *V. wightii* in Peninsular India.

Elevation and temperature has been proved as the most determining variable in habitat modeling of other orchids as *Dactylorhiza hatagirea* (Wani *et al*., 2021) and *Oeceoclades maculata* (Kolanowska, 2013). In other species as *Habenaria suaveolens* (Jalal and Singh, 2017) and *Zanthoxylum armatum* (Xu et al., 2019) precipitation is shown to influence mostly in habitat modeling. However, habitat modeling is generally species-specific and not exclusively confined to any of the variables. Analysis of different variables in the present study indicates that temperature and precipitation are the determining factors on the distribution of *V. wightii*. Inclusion of any of the variables from each PCA component gives similar distribution pattern with minor variation in the percentage contribution and permutation importance. Therefore, temperature annual range, maximum temperature of warmest period and mean temperature of driest quarter are highly correlated ($\gamma > 0.93$) and thus gave similar output as anticipated. Similarly, the high correlation ($\gamma > 0.99$) between annual precipitation, precipitation of wettest period and precipitation of wettest quarter gave similar output.

The conservation introduction attempt at JNTBGRI forest was successful exhibiting luxuriant growth (Figure 5) of seedlings planted on native host trees (Table 5). Out of the 329 seedlings planted in 2015, 63% established when observed after 5 years. JNTBGRI forest is outside the distribution range of *V. wightii* but appeared as a suitable habitat in the generated model. Thus the native hosts as *Terminalia paniculata* and *Tectona grandis* in the introduced location harboring other orchids as *Acampe praemorsa* and *Vanda testacea* through natural recruits are anticipated to support self-sustaining population of *V. wightii*. However, flowering and natural fruit set need to be achieved on the introduced plants for final conclusion on ecological restoration.

Conclusion: V. wightii can sustain in the regions receiving 3518mm mean annual precipitation, 323mm precipitation in the warmest quarter and 11.4°C temperature annual range. The most ideal climatic conditions (0.6-1.0 Class) prevail mostly in, Idukki, Palakkad, Malappuram, Kannur and Kasargod Districts of Kerala in addition to Dakshina Kannada District of Karnataka. However, most of the modeled area in Peninsular India is outside protected forests. Still, there are sufficient locations in protected forests in Kerala for reinforcement of diversity from vulnerable locations in inhabited land, plantations and wayside trees. Conservation introduction outside distribution rage is also possible for the species.

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Fig.1a. *Vanda wightii* in its native locality at Kasargod b. A plant with flower

Fig. 2. Jack Knife test result of regularized training gain

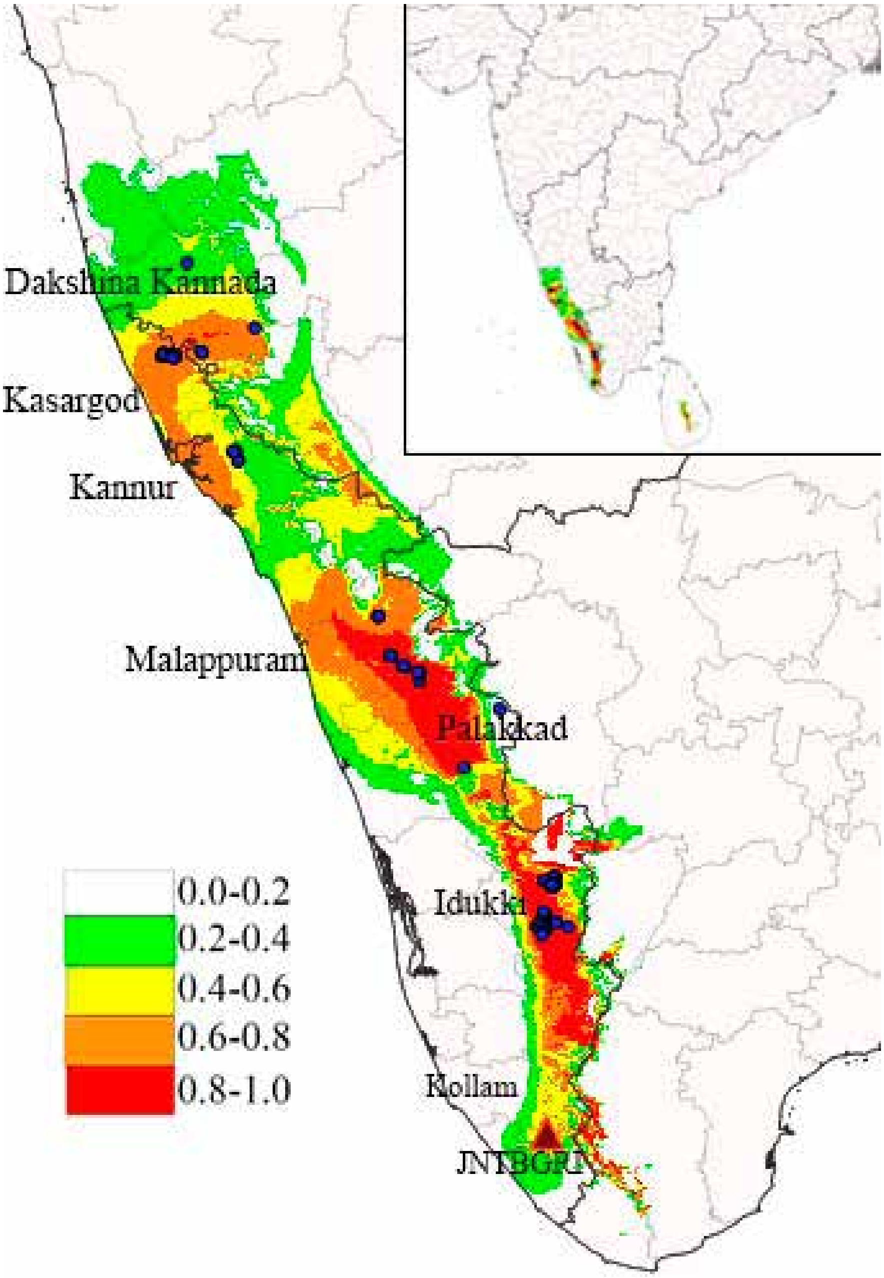

Fig.3. Habitat suitability model of *Vanda wightii* in Peninsular India

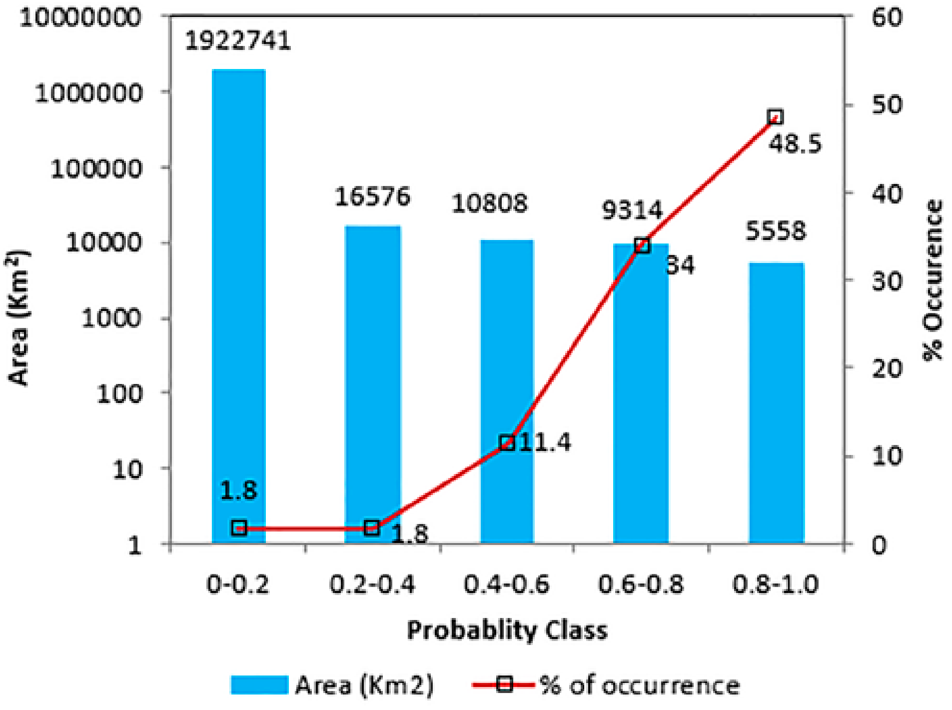

Fig. 4. Area of prediction and percentage of occurrence in the habitat model

Fig. 5a. Seedlings plated on bark of *Terminalia paniculata* as a preliminary step of restoration trial; b. Seedlings on *T. paniculata* showing establishment and luxuriant growth after 5 years of planting

Table 1
Output of Principal Component Analysis (PCA) and Variance inflation factor (VIF) among the variables

Total Variance Explained and Component variables			Principal Components and VIF against one variable taken as constant				
Component	PCA output		PC1		PC2		PC3
	Eigen values	% Variance	Variables*	VIF	Variables*	VIF	Variable
1	4.37	72.93	7		12		18
2	1.01	16.91	5	109	13	1007	
3	0.58	9.67	9	109	16	1007	
Total		99.51					
**7=Temperature annual range; 5=Maximum temperature of the Warmest period; 9= Mean temperature of the driest quarter; 12=Annual precipitation;13= Precipitation of Wettest Period ; 16= Precipitation of Wettest Quarter; 18= Precipitation of Warmest Quarter							

Table 2
Geo-reference points (~1 KM spatial data) of Vanda wighti occurrence in Kerala, Tamil Nadu and Karnataka used for preparing a distribution model

Population	Latitude	Longitude	Altitude (m)	Location	District
1	9.714361	77.0045	902	Idukki WLS	Idukki
2	9.731444	77.01114	744	Idukki WLS	Idukki
3	9.742683	77.02115	784	Idukki WLS	Idukki
4	9.751111	76.994278	850	Idukki WLS	Idukki
5	9.7531	77.1311	929	Kattappana	Idukki
6	9.753178	76.983564	774	Idukki WLS	Idukki
7	9.75438	76.982736	821	Idukki WLS	Idukki
8	9.754380	76.982736	821	Idukki WLS	Idukki
9	9.756842	76.98212	876	Idukki WLS	Idukki
10	9.75965	76.98552	834	Idukki WLS	Idukki
11	9.763739	77.00232	858	Idukki WLS	Idukki
12	9.774333	76.99353	779	Idukki WLS	Idukki
13	9.774436	77.07147	745	Anchuruli	Idukki
14	9.777208	77.06794	946	Anchuruli	Idukki
15	9.780394	77.06120	811	Anchuruli	Idukki
16	9.827	77.01352	1005	Idukki WLS	Idukki
17	9.827003	77.01375	1005	Kalvari mount	Idukki
18	9.9582778	77.048389	752	Marakkanam	Idukki
19	9.959861	77.053889	811	Marakkanam	Idukki
20	9.96225	77.06661	707	Ponmudi dam	Idukki

21	9.9626667	77.06786	789	Ponmudi dam	Idukki
22	9.979111	77.01403	511	Sallyampara	Idukki
23	9.993028	77.06433	807	Thekkumkanam	Idukki
24	10.004028	77.06505	848	Ellakkal	Idukki
25	10.52968	76.62318	381	Pothundy	Palakkad
26	10.8134	76.798567	140	Walayar	Palakkad
27	10.95203	76.40685	81	Meppara	Palakkad
28	10.95212	76.40689	81	Kottoppadam	Palakkad
29	10.99275	76.40948	82	Kottoppadam	Palakkad
30	11.0248	76.32975	55	Pulikkal	Palakkad
31	11.07522	76.266467	57	Melattur	Malappuram
32	11.07703	76.26685	56	Melattur	Malappuram
33	11.26552	76.20875	27	Vadapuram	Malappuram
34	12.02347	75.5256	52	Sreekantapuram	Kannur
35	12.02377	75.525617	52	Madampam	Kannur
36	12.068	75.50135	124	Nidiyanga	Kannur
37	12.06847	75.51473	144	Chepparambu	Kannur
38	12.52468	75.20712	162	Adhoor-Pandi	Kasargod
39	12.53013	75.220867	247	Pandi	Kasargod
40	12.53025	75.21618	207	Adhoor-Pandi	Kasargod
41	12.53038	75.21648	207	Pandi	Kasargod
42	12.53242	75.15928	178	Poovadka	Kasargod
43	12.53335	75.15943	187	Karadka	Kasargod
44	12.53443	75.209	206	Pandi	Kasargod
45	12.53478	75.20245	188	Pandi	Kasargod
46	12.53485	75.202817	188	Adhoor-Pandi	Kasargod
47	12.53507	75.2116	206	Pandi	Kasargod
48	12.53627	75.202817	188	Pandi	Kasargod
49	12.54118	75.16075	187	Karadka	Kasargod
50	12.54825	75.16505	184	Karadka	Kasargod
51	12.55158	75.34815	117	Sullia	Dakshin Kannada
52	12.67065	75.60648	147	Subrahmanya*	Dakhsina Kannada
53	12.985425	75.27697	102	Belthangady*	Dakhsina Kannada
54	15.32925	74.202719	70	Goa**	Goa

*Sathishkumar, *et al* 2006 **Jalal and Jayanthi, 2016

Table 3
Contributions of bioclimatic variables in the model

Bioclimatic variables	Percent contribution	Permutation importance
Temperature annual range (Bio7)	44.9	73.3
Annual mean precipitation (Bio 12)	31.3	8.8
Mean precipitation in the driest quarter (Bio18)	23.8	17.9

Table 4
Temperature and precipitation data relevant to the principal components at occurrence points of *V. wightii*. The data were retrieved from world climatic data using point sampling tool in QGIS.

Temperature			Precipitation		
Variable	Mean±SD	Min-Max in occurrence points	Variable	Mean±SD	Min-Max in occurrence points
BIO_7 (BIO_5 - BIO_6)	11.44±0.67	10.3-14	BIO_12	3518±1190	1580-4912
Bio_5	30.85±2.1	26.7-33.7	BIO_13	1075±515	368-1669
BIO_6	19.4±1.5	16.1-21.2	BIO_16	2421±1145	842-3741
BIO_9	25.5±1.8	21.5-28.4	BIO_18	323.1±30.2	115-381

Table 5
Seedlings of *Vanda wightii* planted on various host trees at JNTBGRI Campus

Hosts	No. of seedlings planted	No. of seedlings established	% establishment after 5 years
Terminalia paniculata	167	125	74.8
Tectona grandis	107	55	51.4
Dalbergia latifolia	20	17	85.0
Careya arborea	10	0	0.0
Alstonia scholaris	15	4	26.7
Total	319	299	63.0